ENGINEERING GRADUATE STUDENTS IN THE K-12 CLASSROOM

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Abstract *— In the fall of 1999, we received funding from the GK-12 program of the National Science Foundation (NSF) to implement a project called "Michigan Tech Graduate Fellows in Copper Country Schools." Funding from the grant provides 10-12 graduate students with a stipend, tuition and fees, and a book allowance each semester. Each GK-12 teaching fellow spends a minimum of ten hours per week providing direct assistance to a teacher(s) in a local school and up to five hours per week preparing outside of the classroom. Local teachers submit mini-proposals describing ways that a GK-12 teaching fellow could help them create "cutting-edge" math and science programs in their school and the GK-12 fellows are then recruited and selected based on their abilities to carry out the work described on the selected teachers' proposals. Supplemental funding was obtained in the first year to provide one fellow and one local teacher with the opportunity for an international exchange. This paper describes the Michigan Tech GK-12 program and presents results obtained in its first two years of operation.*

Index Terms — international programs, graduate education, university/precollege collaboration.

BACKGROUND

Preparing students for the future is one of the principal goals of educational programs at all levels [1]. Reaching this goal, however, depends on keeping courses current and nowhere is that more difficult for educators than in the fast moving areas of science, mathematics and engineering. Furthermore, the general population is demanding an increasing amount of accountability for our educational programs, particularly at the pre-college level. This movement towards accountability has resulted in the development of national, state, and district performance standards for students. As K-12 educators seek ways to transform old courses in these fast moving areas into new state-of-the-art courses, the focus is on three tasks: changes in course content, improved pedagogy, and the use of technology [2]. Course changes often means including new topics, sometimes interdisciplinary ones, and reducing the amount covered in order to allow for better learning. Improved pedagogy usually translates to one or more of the following: active student participation, a constructionist approach, the use of writing, and more projects. With increased use of technology comes a greater emphasis on visualization, the use of calculators, computers, and other equipment. Such technological tools, if properly utilized, can allow students to actively explore material and can extend learning opportunities to a wider variety of students. As pre-college teachers attempt to implement these changes so that their programs and courses are in harmony with state and national standards, the tasks at hand can seem daunting.

It is well documented by various national [3] and international reports [4] that the U.S. needs to improve precollege science and mathematics educational programs to enable our children to compete in the global economy. Teachers are responsible for the delivery of this mathematical and science content and therefore are one of the most important components in the educational programs of K-12 students. Many teachers find themselves being asked to teach mathematics and science courses without certification in these areas due to a lack of qualified applicants for teaching jobs in these fields. These teachers need help in acquiring basic skills in these fields. Teachers who are certified to teach K-12 mathematics and science sometimes find it difficult to stay on the "cutting edge" of their field(s), to integrate the newest technology into their courses, and to develop/modify inquiry-based activities and labs that they would like for their courses. Programs that help K-12 science and mathematics teachers develop the needed expertise, expand and update their current knowledge, learn new technologies and develop materials for their courses are badly needed. If effective, such programs will result in teachers who are able to engage students in meaningful mathematics and science learning.

THE NSF GK-12 PROGRAM

In 1999, the National Science Foundation in the U.S., established the GK-12 program with the following intent:

- enhance the level of interaction in science, mathematics, engineering and technology education among K-12 schools and higher education in ways positive for all;

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- enhance both appreciation and capability of graduate students for high quality science, mathematics, engineering and technology teaching; and
- enhance both appreciation and capability for content-rich, inquiry-based approaches in K-12 schools.

Through this program, graduate students are targeted to work directly with K-12 teachers in and out of the classroom to enhance the teachers knowledge in the content areas, to serve as role models for K-12 students, and to connect K-12 learning to the scientific method. The expected outcomes for this program include:

- improved communication and teaching-related skills for graduate fellows
- content gain and professional development opportunities for K-12 teachers
- enriched learning by K-12 students, and
- strengthened partnerships between higher education institutions and local school districts.

THE MICHIGAN TECH GK-12 PROJECT

In 1999 we received funding from the NSF to establish a GK-12 program at Michigan Tech. This three year program links higher education at Michigan Tech with primary and secondary schools in the Copper Country Intermediate School District (CCISD). Ten graduate students and 2-3 advanced undergraduate students are chosen each year.

Broadly speaking, the goals of this project mirror those of the NSF programmatic goals and are 1) to improve the K-12 mathematics and science programs of schools in the Copper Country Intermediate School District, 2) to develop the professional talents of the participating graduate/undergraduate students and the participating teachers, and 3) to disseminate the best ideas and practices to K-12 mathematics and science teachers both regionally and nationally. Participating teachers frequently ask GK-12 fellows to help develop math and science experiments/labs for the purpose of enabling students to actively engage in "doing" and learning the subject matter, to develop family math and science programs, to help them apply the tools of technology in the classroom, to share their special academic interests with K-12 students, and to discuss career options within their fields of study. As university students in a K-12 environment, the fellows are automatically role models and can help motivate the younger students to consider careers in mathematics, science, and engineering.

Teacher Proposals

Teachers from area schools are asked to submit proposals for projects in their classes that could be implemented with assistance from a GK-12 fellow. These proposals are submitted to the Math and Science Center of the CCISD for selection based on two primary factors: 1) quality of proposal/ideas, and 2) demonstrated need for improvement in a particular school district or at a particular grade level.

The range of topics for teacher requests is very broad. In some cases, teachers have asked for assistance in developing activities suitable for second grade science, whereas other teachers have requested help in developing AP Biology or Chemistry courses. In some instances, teachers in one district have worked together to bring about changes in a number of courses, while others have focused on the development of specific units for use within the curriculum at a particular grade level. A sample of supported projects is:

- Scientific Inquiry in the 4th Grade
- Building Educational Web Sites
- Exploring Math and Science through Data Collection
- Second Grade Scientists
- Implementing Computer Standards in the Elementary Curriculum

Teachers selected for participation in the program are eligible to apply for funds for science supplies or equipment for their schools. In some case, larger pieces of equipment were purchased with grant funds through the "lending library" arm of the CCISD.

Student Applicants

Electronic application materials for the program were developed for the web. All graduate advisors and chairs at Michigan Tech have been educated regarding the program and encourage their students to apply for these fellowships each year. To qualify for a fellowship, students must be a U.S. citizen majoring in mathematics, science, or engineering, be a full time graduate or advanced undergraduate student, and have their own car. A GK-12 fellowship includes a graduate student stipend, student tuition and fees, and a textbook allowance. Undergraduate fellowships consist of stipends only. Each GK-12 teaching fellow spends a minimum of ten hours per week providing direct assistance to a teacher(s) in a local school and up to five hours per week preparing outside of the classroom. Fellows are required to keep a journal of their activities relative to their work in the program.

Through the application process, graduate students are invited to prepare a proposal of a session that they would like to conduct from their field of interest in the K-12 classroom. Applications are reviewed and applicants selected based on two primary factors: 1) their background in math and science and their ability to carry out the work described on the selected teachers' proposals, and 2) their communication skills and perceived enthusiasm. The majority of students in the program for the past two years have been engineering students.

Communicating Science

In order to help the beginning GK-12 teaching fellow develop his/her oral and written communication skills for work in the schools, all fellows take a 2-credit course in the fall semester titled "Communicating Science." In this course the fellows are taught to develop lesson plans and to develop age-appropriate oral and written materials. Fellows are also familiarized with the national and state standards and the Michigan Educational Assessment Program--some of the driving forces behind the course and program changes that teachers request. During the semester, the fellows also help deliver Family Science and Family Math nights at local schools as part of their assigned work for this course.

Family Math and Family Science nights have been delivered in our local elementary schools for several years by the CCISD Math/Science Center. During these events, children are divided by grade level to conduct various hands-on activities with their parents. Each child attends two 40-minute activities followed by refreshments in the school cafeteria. Fellows (along with other participants from the Communicating Science course) work to develop their lesson plans during the first few weeks of the semester (in some cases, fellows may adapt previously developed activities for the program) and then conduct these evening activities among groups of up to 40 children and their parents a total of three times during the remainder of the semester. Sample titles of some Family Math and Science activities are:

- Red Hot Lava
- Magnetic Attraction
- E.G.G. D.R.O.P.
- How Much Water is in the World?
- Ooey, Gooey Slime

Feedback from the children and parents who have participated has been overwhelmingly positive for these Family Math and Science nights. In addition, GK-12 fellows have indicated that the Communicating Science course has been instrumental in helping them as they develop their K-12 teaching skills.

International GK-12 Exchange

In the summer of 2000 we received supplemental funds from NSF to support one graduate student and their cooperating teacher for a one-month research/teacher interaction experience in Malaysia. Elly Bunzendahl, Master's candidate in Environmental Engineering and Kathleen Lewandowki, a fifth grade teacher at Lake Linden Elementary worked with researchers from University of Science at Penang and with primary school teachers in the area. The experience allowed an exchange of expertise in water quality research, educational pedagogy and teaching resources.

Elly and Kathleen worked with researchers to explore the problems that affect the water quality in Malaysia. Environmental controls and practices in Malaysia are decades behind the rest of the developed world, due to limited funding for research. The information that they gathered was used to develop lesson plans and hands-on activities for primary school teachers concerning water resource monitoring and management. Workshops were conducted at various primary schools in Malaysia on how to implement these activities in the classroom. In addition, other workshops were held to provide teachers with strategies to incorporate hands-on science and mathematics activities into their curriculum. The use of hands-on activities has been very limited in Malaysia due to a rigid curriculum and standardized testing that leaves very little flexibility in the use of class time. The teachers that participated in the workshops saw these activities as a valuable way to engage students in meaningful learning that they can relate to real world problems.

This experience promoted a continual cultural exchange between the educational community in Penang and educational community in the Houghton area. Research connections between MTU and University of Penang have been established that will allow collaborative work in the area of water resources. Educational connections between the primary school in Penang and Lake Linden have fostered communication between students and teachers concerning education and culture.

Program Administration

The PI for the proposal, Dr. Beverly Baartmans, serves as the program director. The project director has been responsible for overseeing the various aspects of the program including coordinating the student application and selection activities, interacting with the fellows and the CCISD on a regular basis, solving problems as they arise, and serving as the Michigan Tech point of contact for external constituencies (i.e., the NSF and the CCISD). Ms. Shawn Oppliger, director of the Math and Science Center of the CCISD, has been the main point of contact for teachers and school administrators who have been working with the GK-12 fellows. In this role, she has contacted teachers with requests for proposals each year, has coordinated selection of teacher projects, and has facilitated communication between the university and the local schools.

In addition to these two program leaders, there have been several committees that have assisted in carrying out the various major activities associated with this program. There have been three main committees that have been working on this program. The Project Selection Committee meets in February of each year to review teacher proposals and to select those for implementation. This committee consists primarily of local school administrators along with staff from the CCISD. The Fellow Selection Committee meets in the late winter of each year to review graduate applications

and to select students for interviews.This committee is composed of the project principals as well as local school administrators and program PIs. The committee meets individually with student applicants (by conference call for those students who are not available on campus) to assess their communication skills and general attitudes. After interviews are completed, the committee selects the graduate students for participation and determines which teacher project each should serve. The Allocation Committee meets each spring to review teacher supply budget requests and to distribute funds accordingly.

Program Assessment

Since this is a three-year program and we are currently ending our second year of the program, the feedback and assessment information reported here is based only on the first two years of the program. Longer term objectives obviously cannot be evaluated until a later time. Project objectives supporting the overall goals of the program are listed below with current assessment results or the status of the assessment mentioned for each objective.

Objective 1. For schools and students directly affected by the program, Michigan Educational Assessment Program scores in the areas of mathematics and science will improve over the three-year period. The data needed to assess the accomplishment of this objective will not be available until the third year of the project.

Objective 2. For courses directly affected by the program, these courses will more fully align with national and state mathematics and science standards. Twenty participating teachers completed an end of the year final evaluation form. On Part A of this form teachers were asked to check off the Michigan Mathematics, Science and/or Technology Content Standards that their project addressed. Of the twenty teachers who responded, 17 checked one or more mathematics standards addressed by their projects, 18 checked one or more science standards being addressed by their projects and 16 checked one or more technology standards being addressed by their projects. Across all 20 teachers responding, the average number of math, science, and technology standards reportedly being addressed were 5.25, 4.2, and 2.25, respectively.

Objective 3. Participating graduate and undergraduate students will improve their communication and teaching skills and become more aware of ways they can contribute professionally to local schools. During the Communicating Science course, GK-12 teaching fellows were pre- and post-tested on a 13 item self assessment measure and asked to respond to each question using a scale from 1 to 10 (1 = strongly disagree, 5 = neither agree nor disagree, and 10 = strongly agree). Table I summarizes fellow responses to the indicated questions for pre- and post-testing.

TABLE I
PRE-/POST-TEST RESULTS

Question	Avg. Pre-Test	Avg. Post-Test
1. I am confident in my current ability to effectively communicate what I know to K-12 students and the community.	7.07	8.7
2. I believe it is an important civic responsibility to help educate children and adults in the community about the relevance of science in their everyday lives.	8.73	8.60
3. I enjoy teaching.	7.13	8.73
4. As a professional, it is important for me to have good oral and written communication skills.	9.64	9.71

The average gain scores on questions 1 and 3 were statistically significant ($p<0.005$ for each). The gain scores on questions 2 and 4 were not statistically significant, however, the pre-test score for each item was high from the outset, indicating the relative importance of these items for this group of students.

Objective 4. As a group, the participating teachers will become more knowledgeable about both the content and application of science, engineering and technology. Teachers were specifically asked on Part B of the final evaluation form about their increase in knowledge in content areas and about applications. Table II summarizes teacher responses to two key questions.

TABLE II
TEACHER SURVEY RESULTS

Question	Yes	No	Uncert.
1. Have you as an individual become more knowledgeable about a content area as a result of the GK-12 teaching fellow's work in your school?	15	5	0
2. Have you as an individual become more knowledgeable about applications as a result of your GK-12 teaching fellow's work in your school?	12	3	5

Objective 5. A greater number of professional development opportunities for local teachers will be made available as a result of increased communication between university faculty and local teachers. The professional development activities for teachers that have been a direct result of this project are:

- A week-long workshop titled "Computing in the Classroom" for K-8 teachers was offered in the summer of 2000 with twenty-six area teachers in attendance.

- Cooperating elementary school teacher attended a 2-day Family Math training program with the Communicating Science instructor.
- Secondary chemistry teacher attended the NSF GK-12 Principal Investigator's 2-day conference in Washington D.C. in March 2000.
- Elementary school teacher and her GK-12 teaching fellow spent July 2000 in Malaysia visiting schools and universities there as part of the global component of this program, as described previously in this paper.
- Participating teachers will be giving talks over their best ideas and practices as a result of the GK-12 program at the summer 2001 regional conference.
- Cooperating elementary school teacher conducted a session on her work with the graduate fellow at the National Science Teachers Association Conference in St. Louis in March 2001.

Objective 6. Best ideas and practices from this project will be disseminated regionally through a summer workshop for Upper Peninsula K-12 mathematics and science teachers and nationally through mathematics and science education conferences. Since the summer workshop is scheduled for July 23-24th, 2001, there is no assessment data to report on the conference at this time.

Program Dissemination

Dissemination of the best ideas and practices from the Michigan Tech GK-12 program has been conducted through a variety of avenues such as presentations at the National Council of Teachers of Mathematics, the National Science Teachers Association, the American Association of Engineering Educators, and the Michigan Computing Teacher's Association and through written articles in professional journals and conference proceedings. In addition, we are currently planning a regional conference titled "Michigan's Upper Peninsula K-12 Teachers Conference on Mathematics and Science Education" to be held at Michigan Tech, July 23-25, 2001. This regional conference will feature talks by the participating teachers and fellows in the GK-12 program on the best ideas and practices that they have created over its first two years of the program. The intended audience for this conference is certified K-12 math and science teachers in the region. A sampling of talk titles for this conference includes:

- Elementary Science Labs--Hands On
- A School Forest
- Family Fun Night
- Introducing the CBL into Algebra I
- Think Quest--A Web Page Design Competition for 4th-6th Graders
- Mentoring MultiMedia Presentations

CONCLUSIONS

In order for our children to be able to cope in our increasingly technological society, it is vitally important that they have well-grounded math and science skills. Engineering graduate students can play a critical role in improving math and science instruction for precollege students. The GK-12 program developed by the NSF and implemented at Michigan Tech seems to be improving math and science instruction in the school districts in the Copper Country of Michigan. Through this program we have also improved relations between the university and the local community and have instilled in our graduate fellows a sense of appreciation for problems faced by precollege teachers and students. It is our hope that these graduate fellows go on to become leaders in working with schools in the communities where they eventually find employment.

ACKNOWLEDGMENT

The authors would like to gratefully acknowledge the National Science Foundation for their support of this work through grant No. DGE-9979572.

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